

# EIC Modular RICH Detector Simulation Update

Liang Xue  
for the eRD11 Collaboration

Georgia State University

# eRD11 Project Status

- Detector concept and GEANT4 simulation status
  - *Modular aerogel RICH will be presented in this talk*
  - *A focusing / proximity focusing aerogel RICH are next in line*
  - *A new post-doc is found for dual-radiator RICH study*
- A particle ID consortium meeting has been formed by TOF, RICH, DIRC R&D group. A joint proposal will be prepared for coming July meeting.

[https://userweb.jlab.org/~yqiang/files/eic\\_rich/20140627\\_EIC\\_RICH\\_RnD\\_final.pdf](https://userweb.jlab.org/~yqiang/files/eic_rich/20140627_EIC_RICH_RnD_final.pdf)

# Outline

- Modular RICH detector (10 cm x 10 cm x 10 cm) has been constructed and studied in JLab GEant4 Monte-Carlo (GEMC) framework.
  - Material quantum efficiency is implemented for GaAsP as photonsensor detector.
  - Non-uniformity of aerogel and fresnel lens is mimicked by smearing photon-electron position on the photonsensor detector.
  - Detector noise is mimicked by throwing electron randomly on the photonsensor detector

<https://gmc.jlab.org>

- Particle identification performance is studied using maximum likelihood analysis technique with single particles for a single RICH module.
- RICH modules are stacked (both eta and phi projective) together in jlab MEIC environment for further study.

<https://github.com/EIC-eRD11>

# Modular RICH In GEMC

## 1) A block of aerogel.

- SiO<sub>2</sub>, 0.02 g/cm<sup>3</sup>
- Refractive index: n=1.025

## 2) Fresnel lens

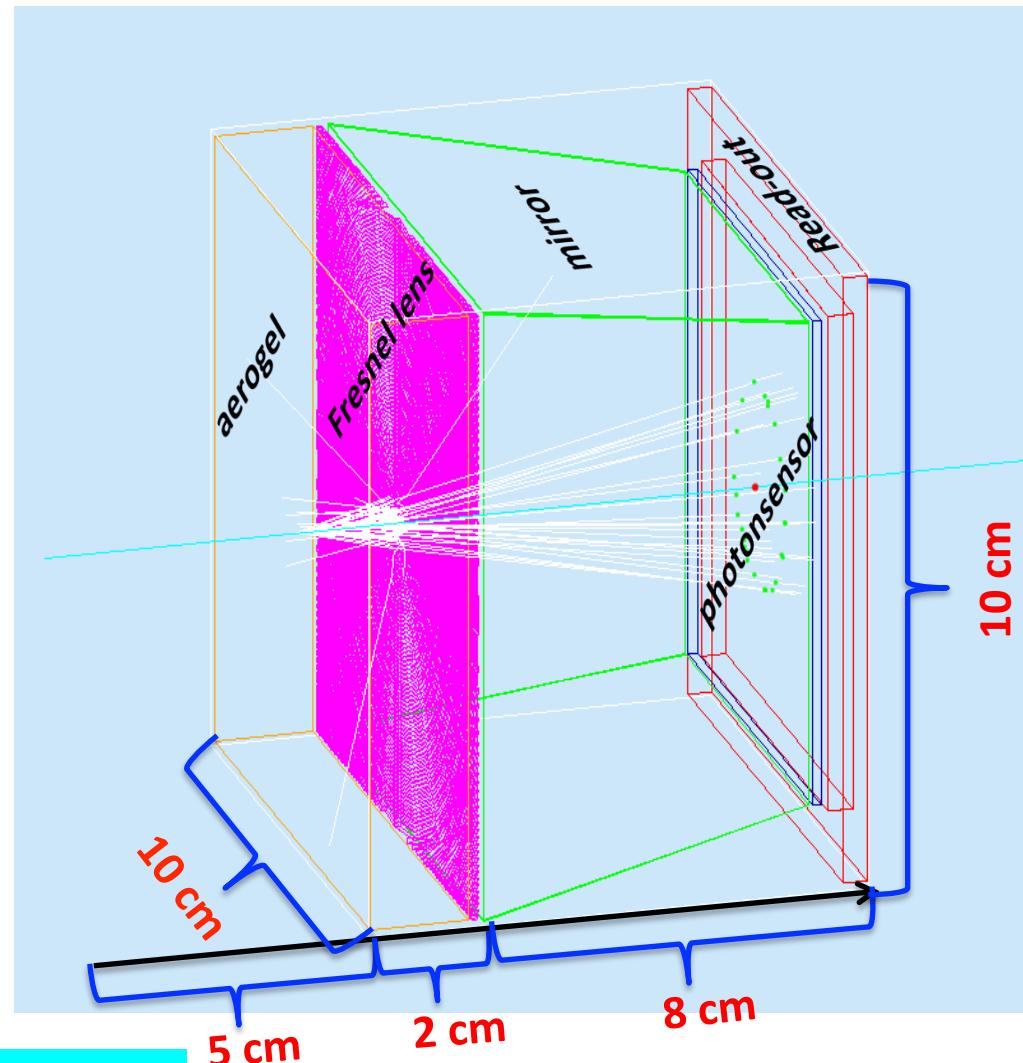
- Acrylic, C<sub>5</sub>H<sub>8</sub>O<sub>2</sub>, 1.19 g/cm<sup>3</sup>
- Four sections, G4Polycon
- 100 grooves, good focusing

## 3) Mirrors

- Four sections: front, back, top and bottom
- Reflectivity index : 0.95

## 4) Photosensor and read-out

- Block of aluminum



Fully implemented in GEMC framework

# Likelihood Analysis

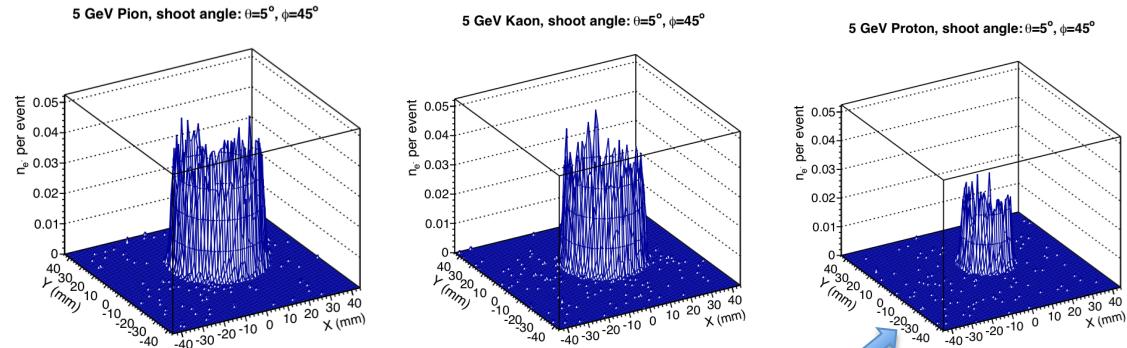
## Analysis Procedure:

- Given momentum, the detector responses for different particle species are different.
- Calculate the detector responses for each particle ( $\pi$ , K, proton) at particular momentum in GEANT4 simulation. Build a detector response database as a function of the momentum and detector position.
- Given unknown incoming particle, do PID by comparing its detector response with that from database.

## Detector facts:

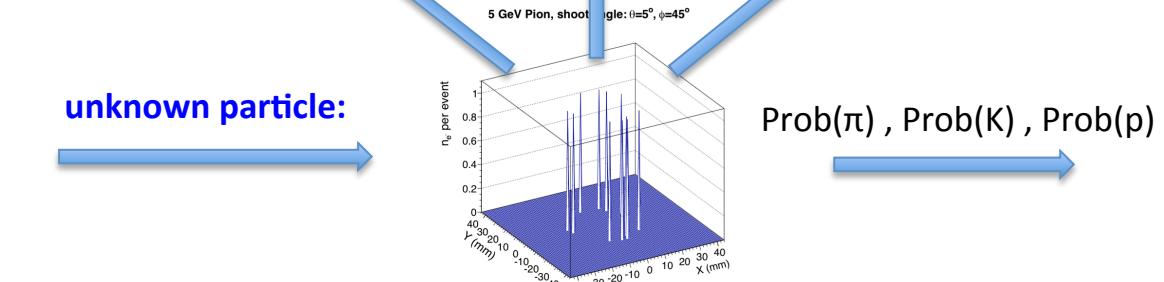
- Photonsensor : 88 mm x 88mm
- Segmentation: 1mm x 1mm
- # pads: 88 x 88
- $N_e^-$  in each pad following poisson distribution
- If  $N_e^-$  is 0, a noise of  $2/88./88.$  (2 electron in the detector) is setup.
- 2 e- with random position added to each events as noise.

## Detector Responses:



## Particle Identification: Bin by Bin

unknown particle:

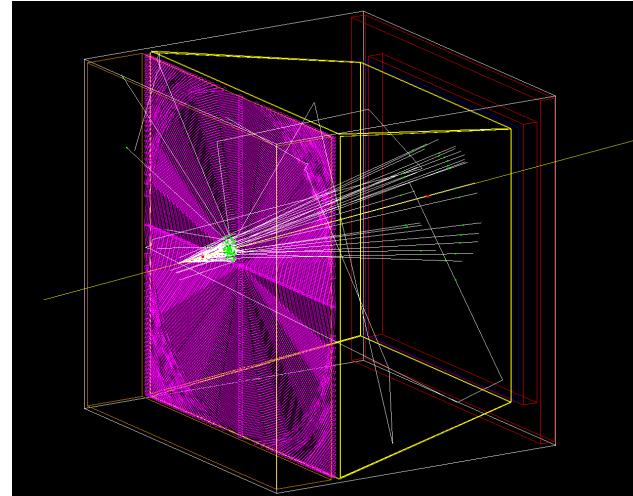


# GEANT4 Simulation Data

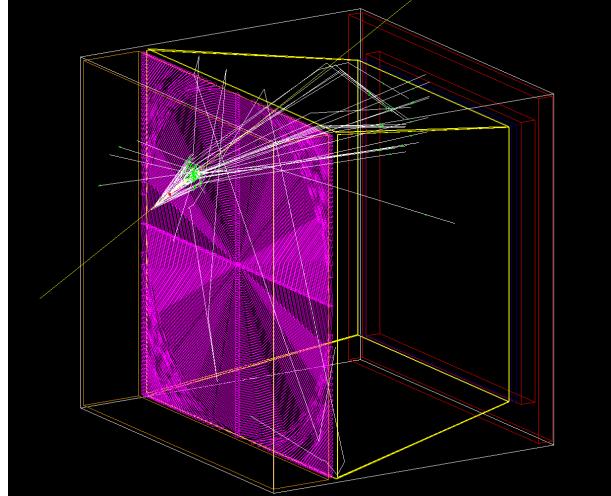
GEANT4 simulation data is generated:

- Particle:  $\pi$ -, K-, and proton
- # events: 549 k (1 k / particle / momentum / Shoot angle)
- Momentum: 3 to 15 GeV, with a step of 0.2 GeV
- Theta angle:  $5^\circ$ ,  $25^\circ$ ,  $45^\circ$  (from center to corner of the detector)
- Phi angle: fixed to  $45^\circ$  degree

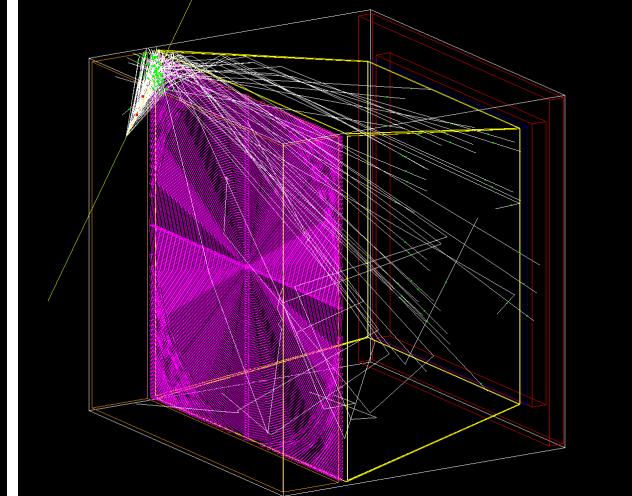
Theta=5°; Phi=45°



Theta=25°; Phi=45°



Theta=45°; Phi=45°



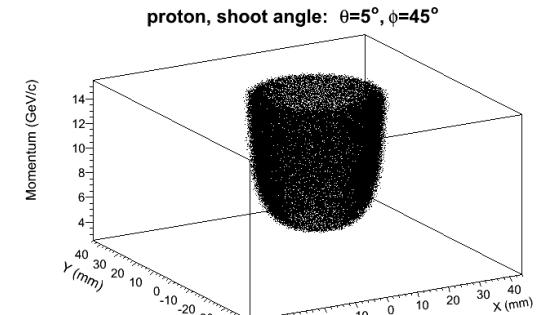
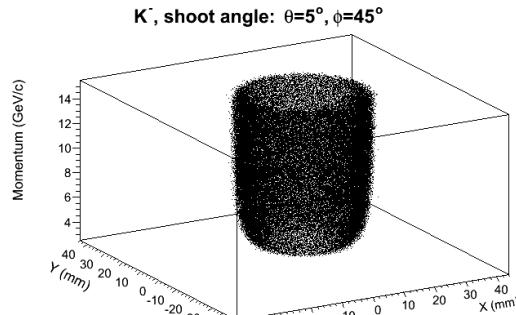
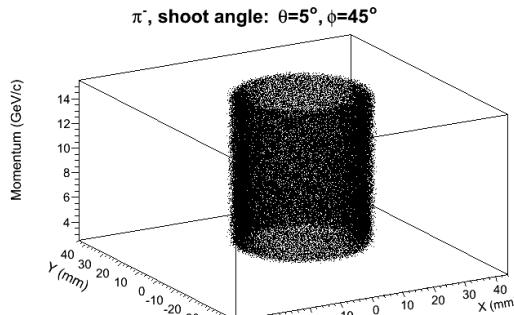
# Detector Response Database

$\pi^-$

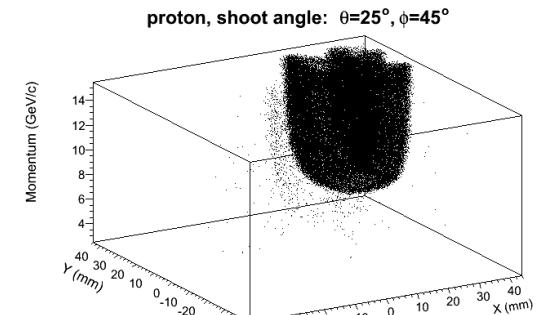
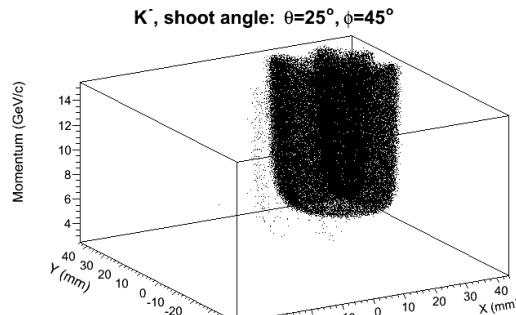
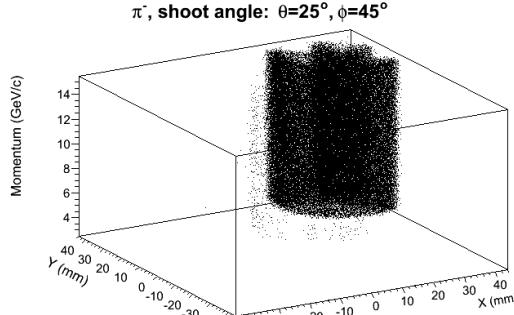
$K^-$

proton

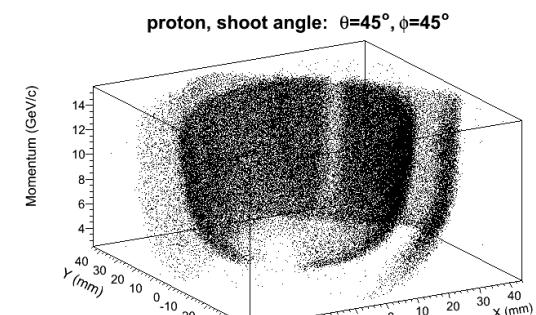
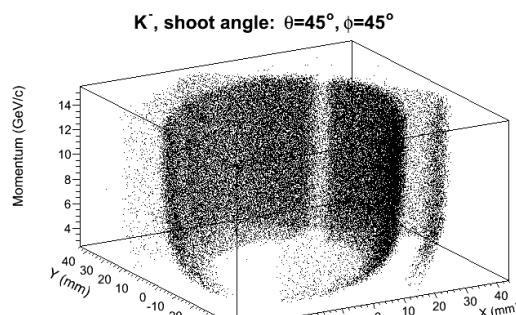
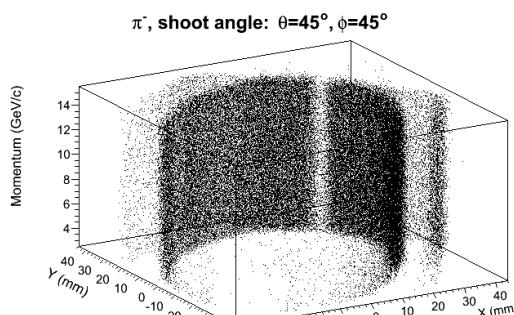
Theta=5° Phi=45°



Theta=25° Phi=45°



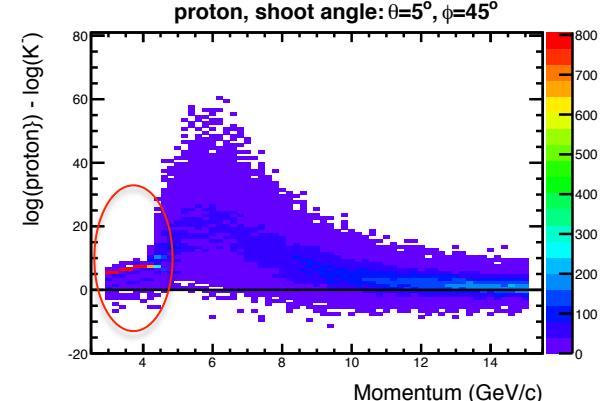
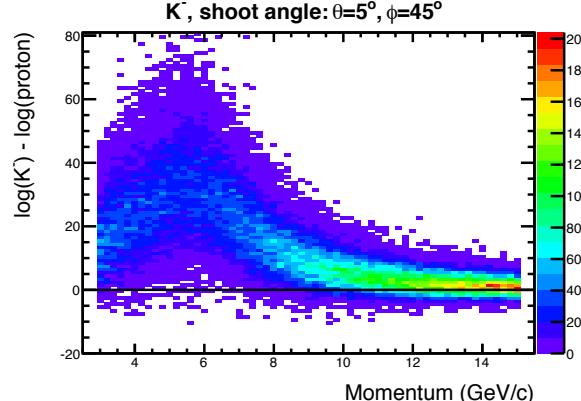
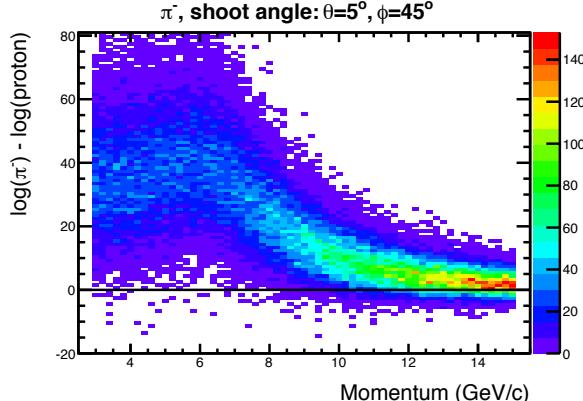
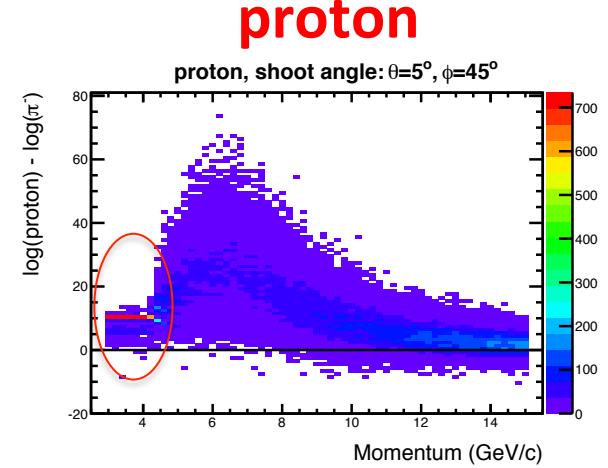
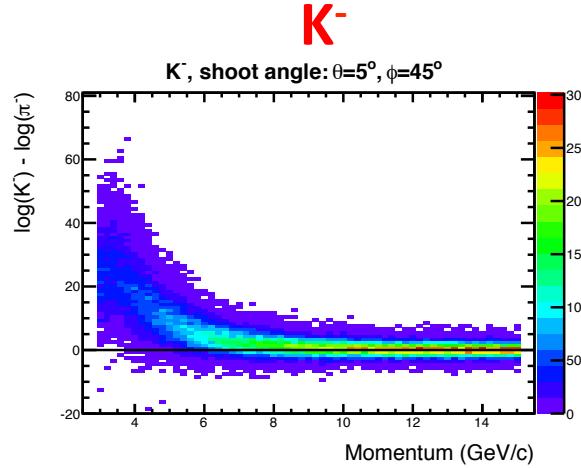
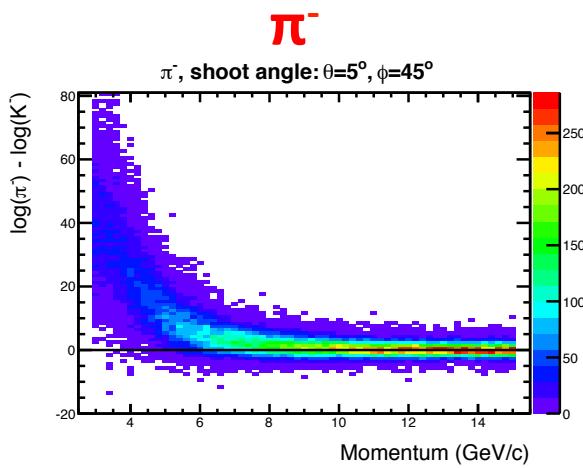
Theta=45° Phi=45°



# Likelihood Probabilities (Theta=5, Phi=45)

## Log likelihood PID:

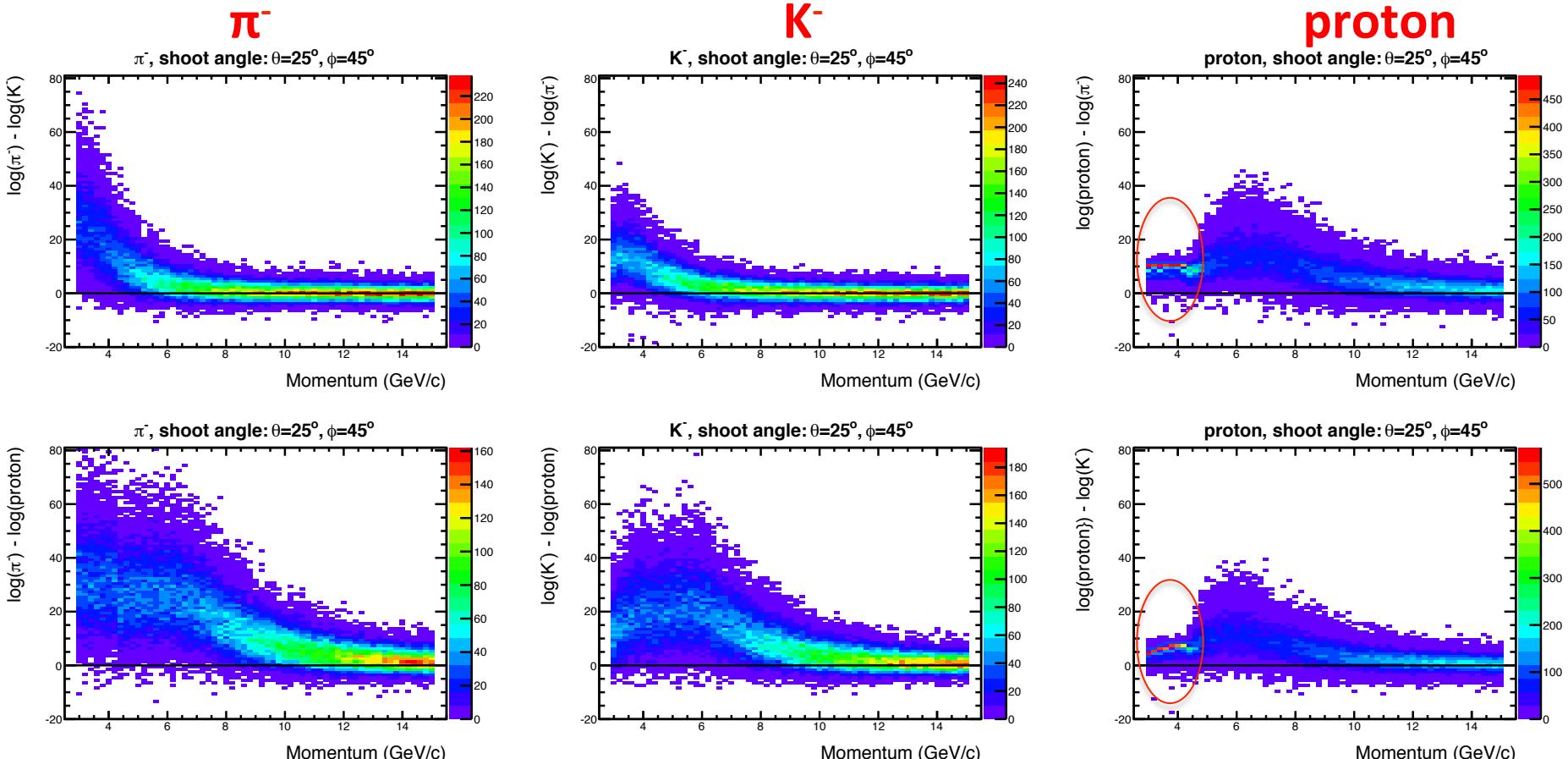
- $\pi$ -, K-, and proton can be identified using log likelihood method
- $\pi$ -, K- can not be identified with momentum  $> 10 \text{ GeV}/c$
- Proton at low momentum ( $< 4 \text{ GeV}/c$ ) still can be identified, even no Cherenkov photon / photonelectron created.



# Likelihood Probabilities (Theta=25, Phi=45)

## Log likelihood PID:

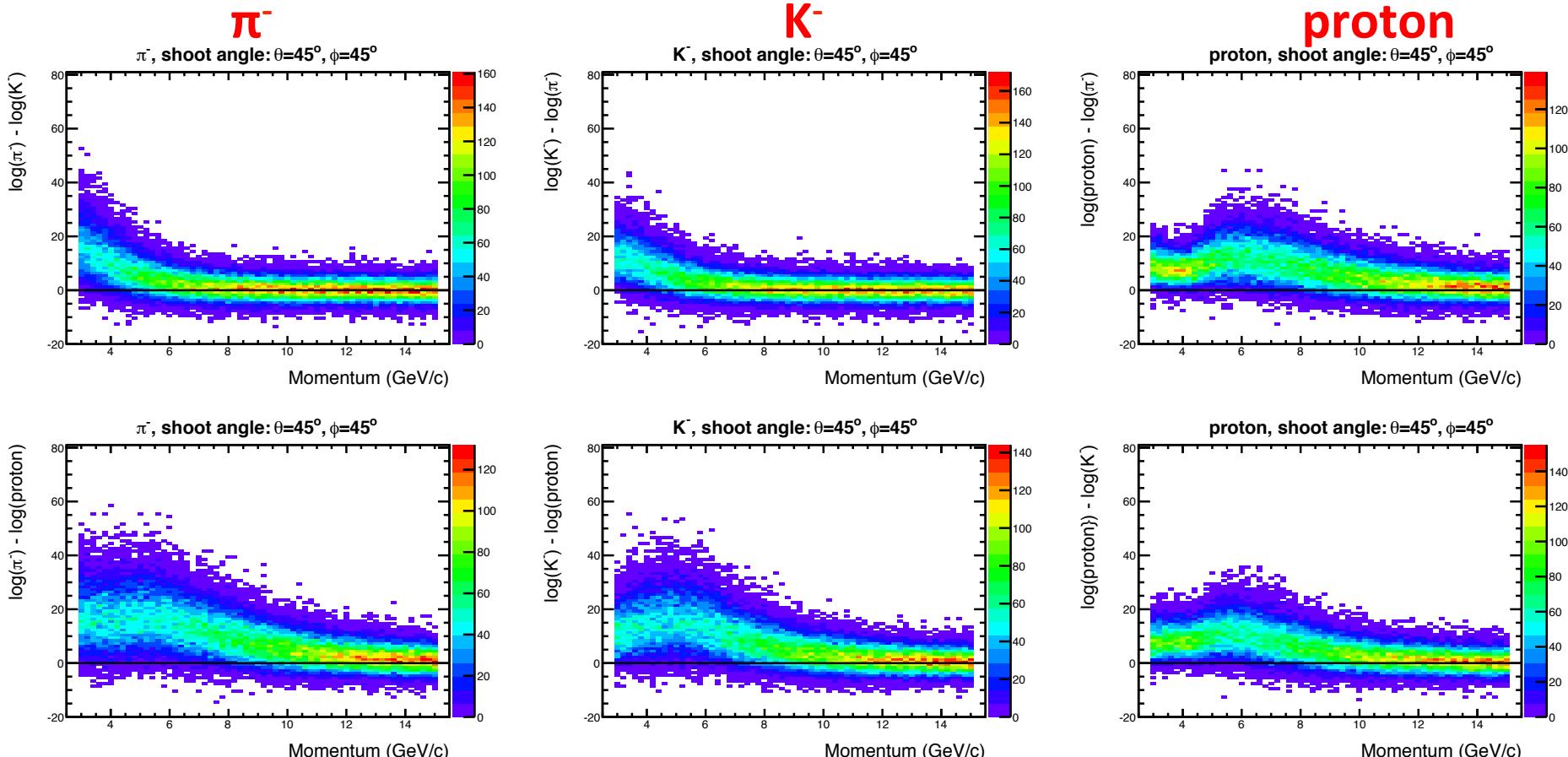
- $\pi$ , K- can not be identified with momentum > 10 GeV
- Proton at low momentum (<4 GeV) still can be identified, even no Cherenkov photon / photonelectron created.
- log probability difference smaller (means harder for PID), if compared with theta=5, phi=45



# Likelihood Probabilities (Theta=45, Phi=45)

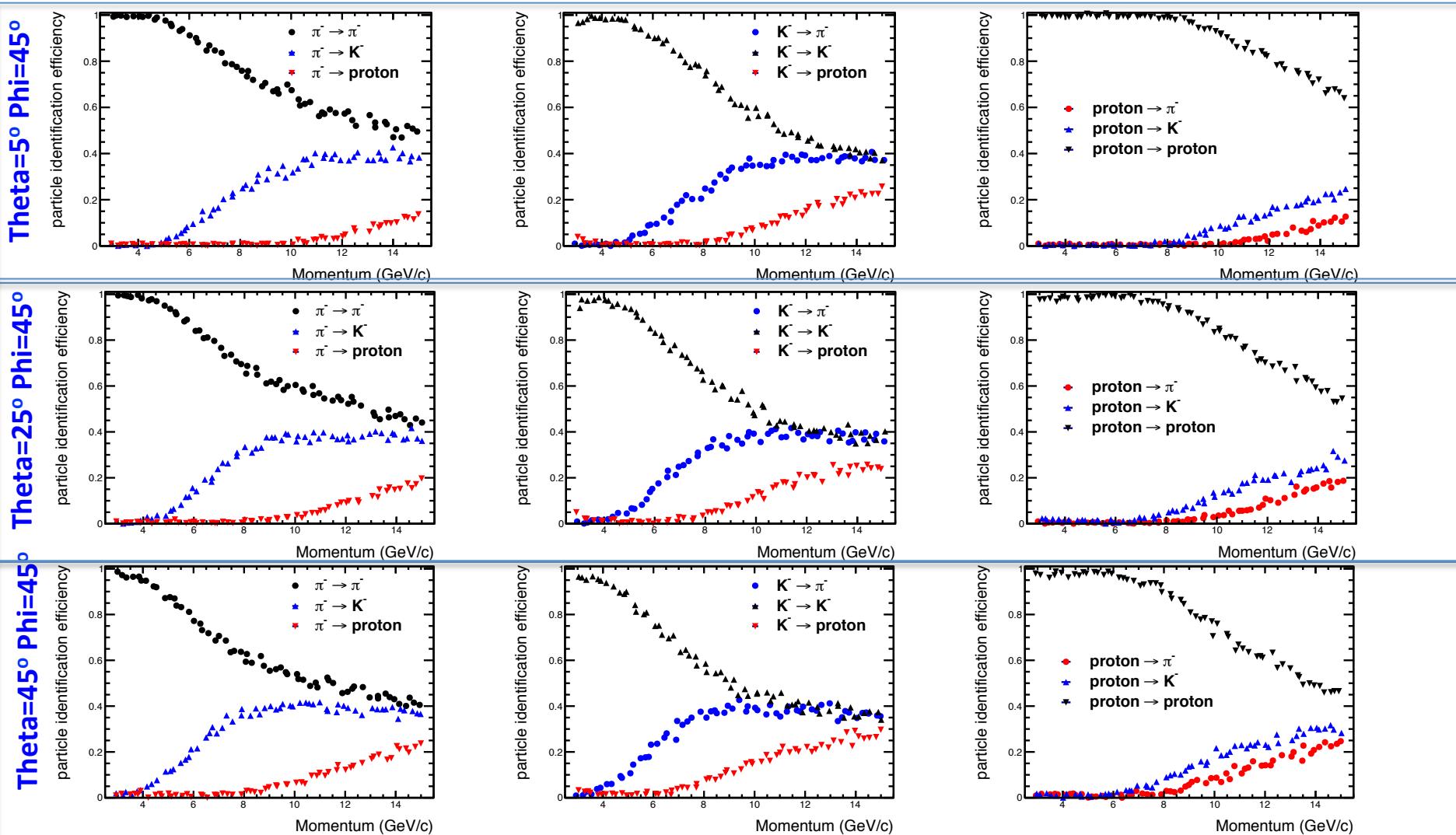
## Log likelihood PID:

- $\pi^-$ ,  $K^-$  can not be identified with momentum > 10 GeV
- log probability difference smaller (means harder for PID), if compared with theta=5/25, phi=45

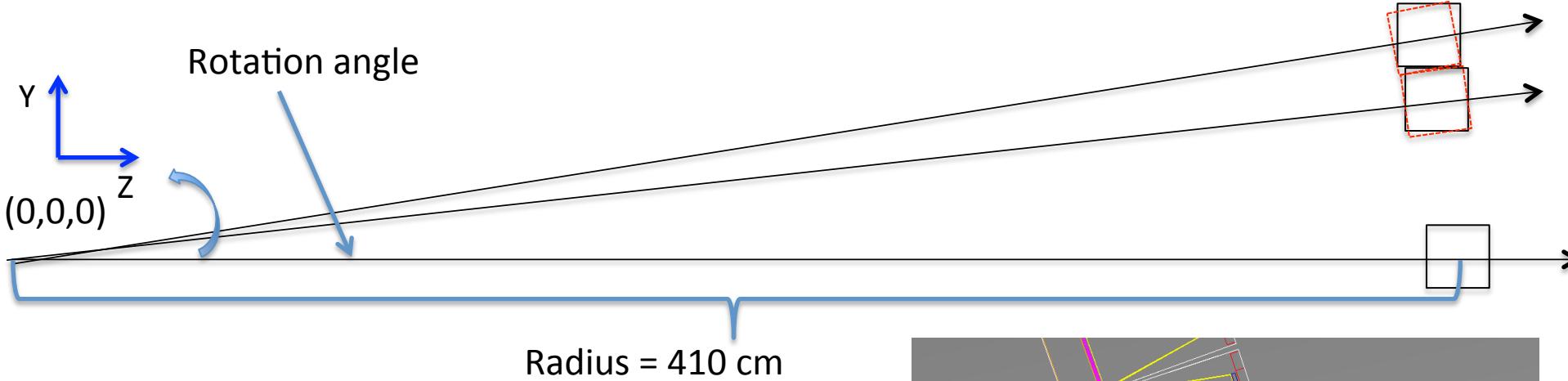


# Particle Identification efficiency

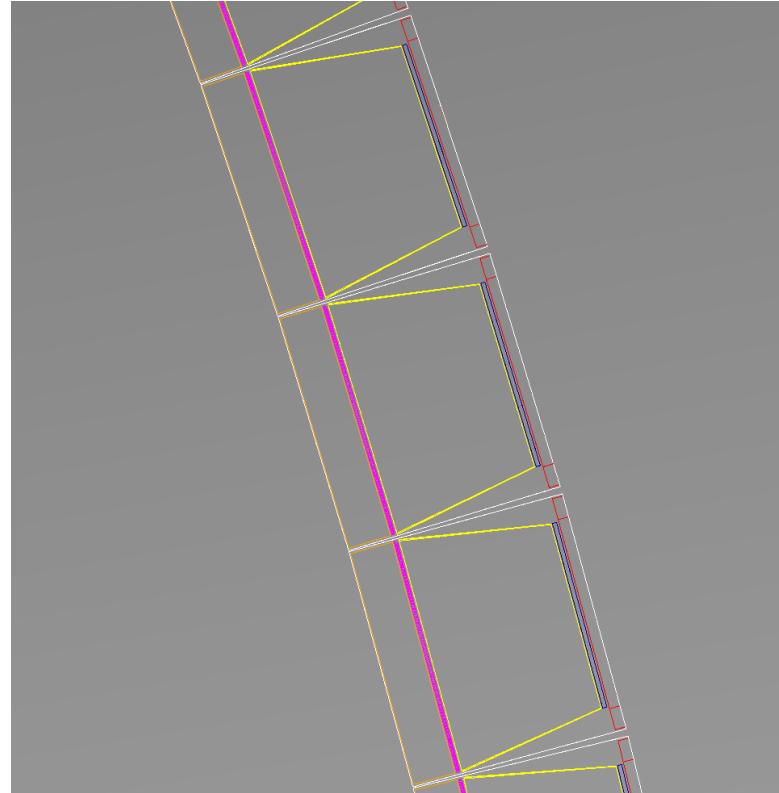
- PID efficiency decrease, and mis-PID increase as a function of momentum.
- At 10 GeV/c, PID efficiency are  $\pi^-$ : 60%,  $K^-$ : 55%, proton: 90%
- PID performance with particle shoot the corner is worse than that with particle shoot the center of detector



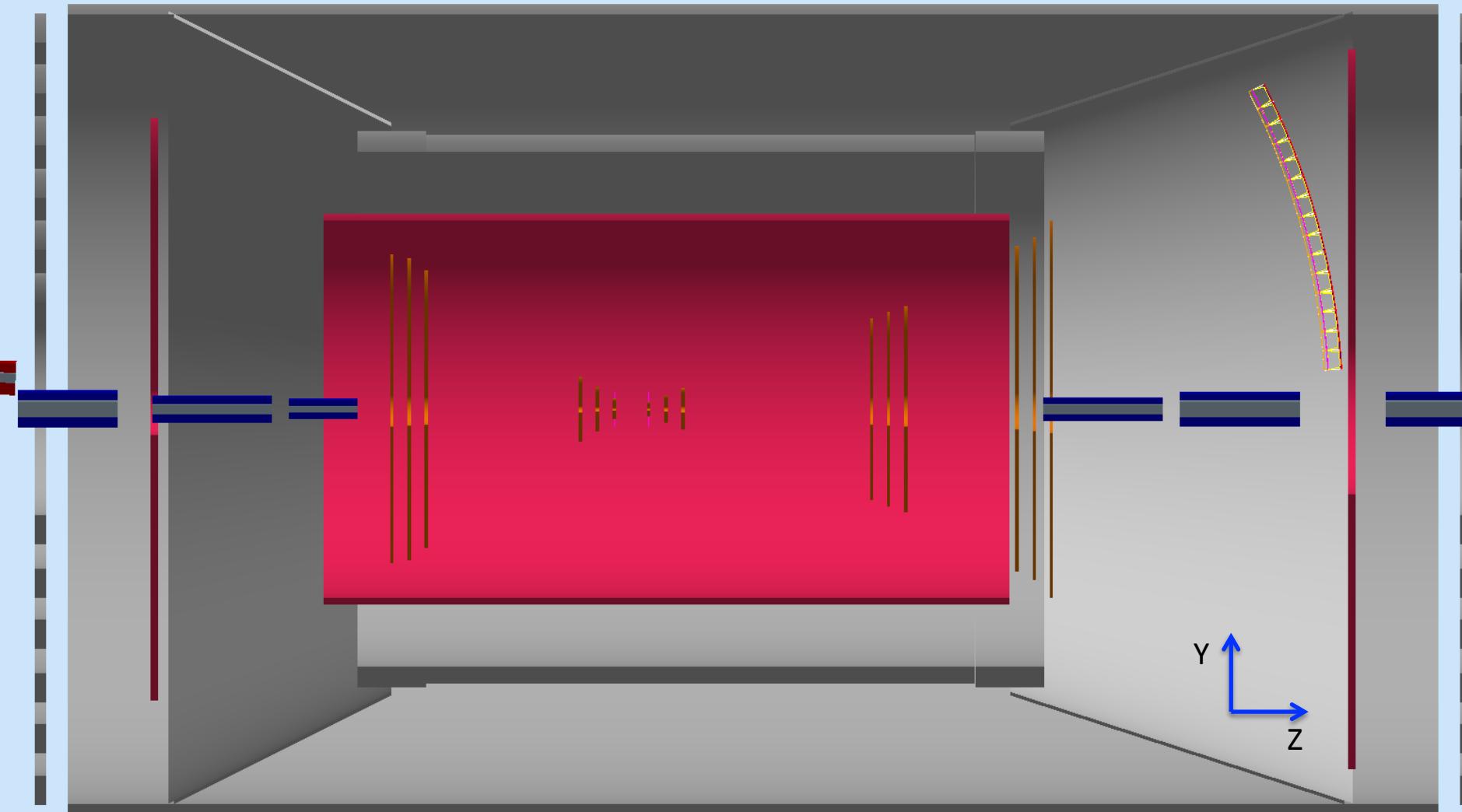
# Pseudo Rapidity Projective



- Detector position for each RICH module is calculated using radius and rotation angle.
- Each RICH module is rotated wrt. itself to make it pseudo rapidity projective.

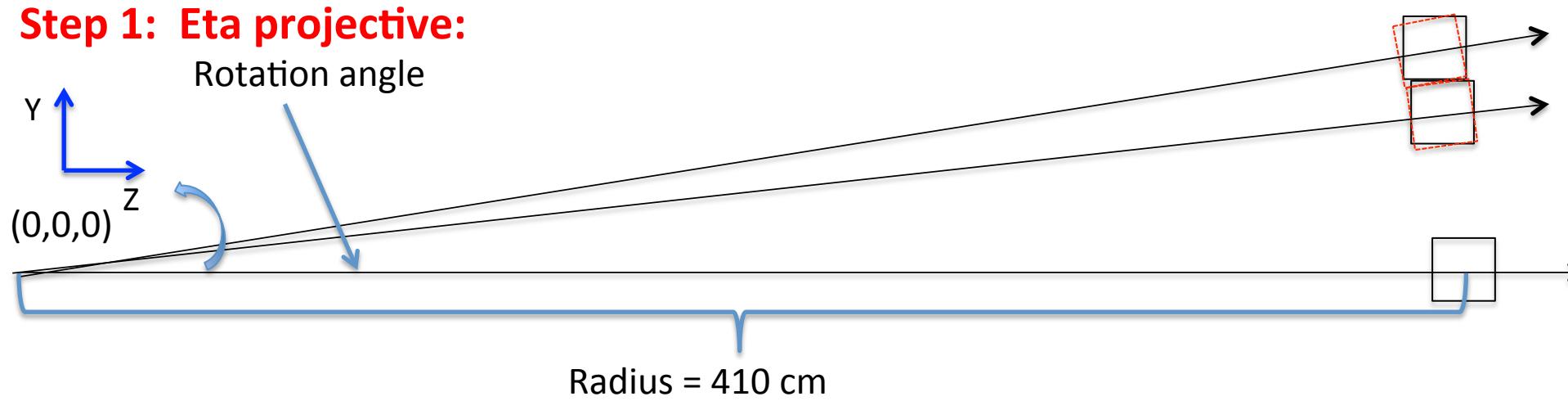


# Pseudo Rapidity Projective (cnt)

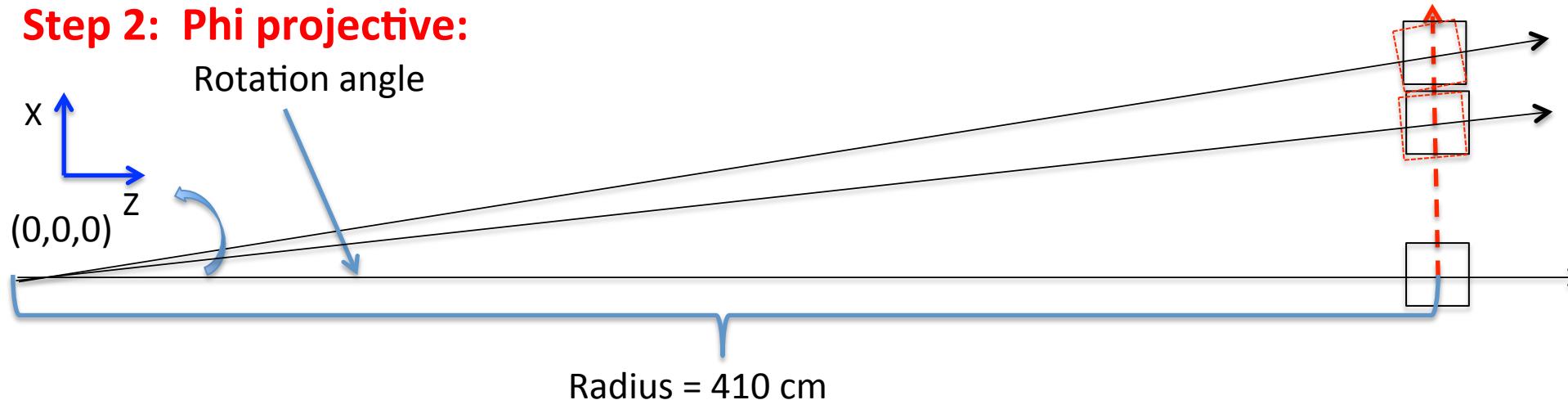


# Both Eta and Phi Projective

## Step 1: Eta projective:

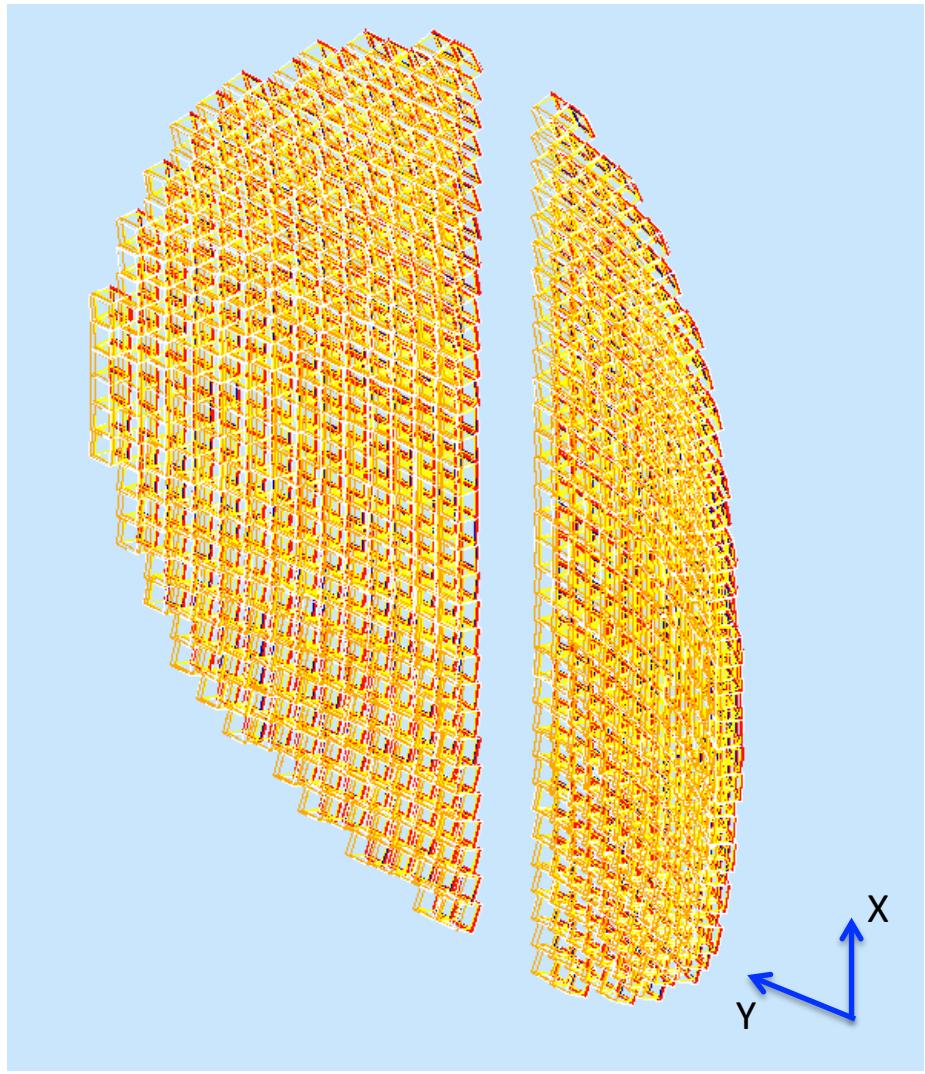
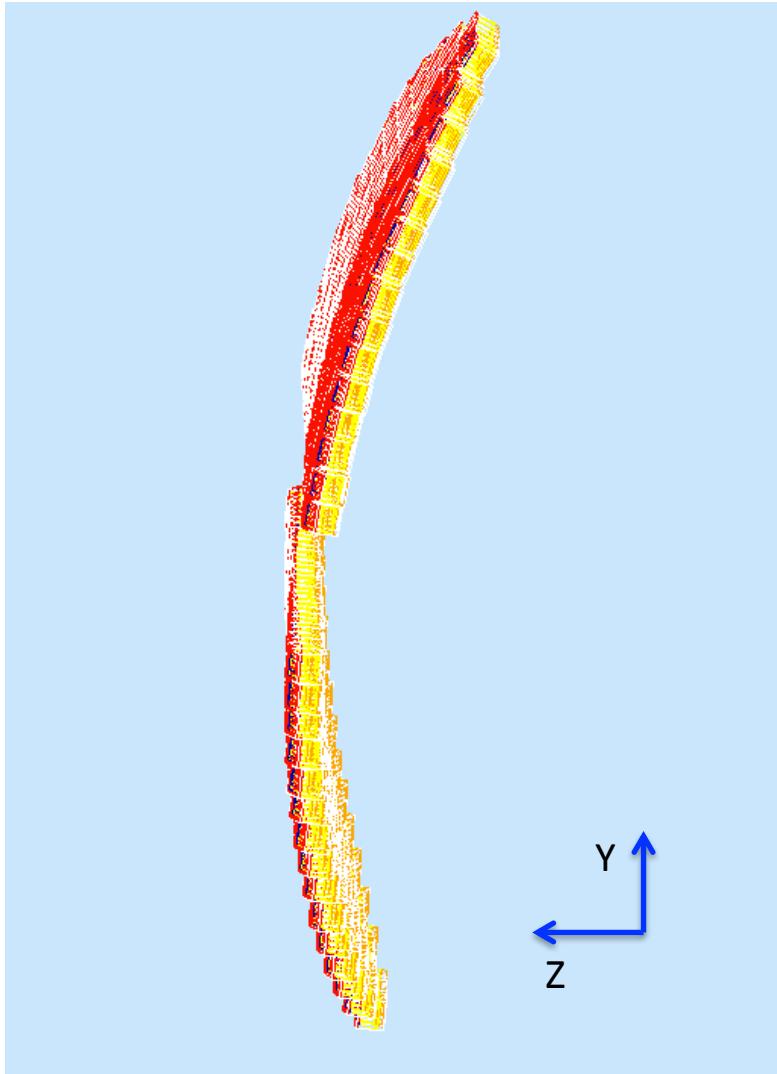


## Step 2: Phi projective:

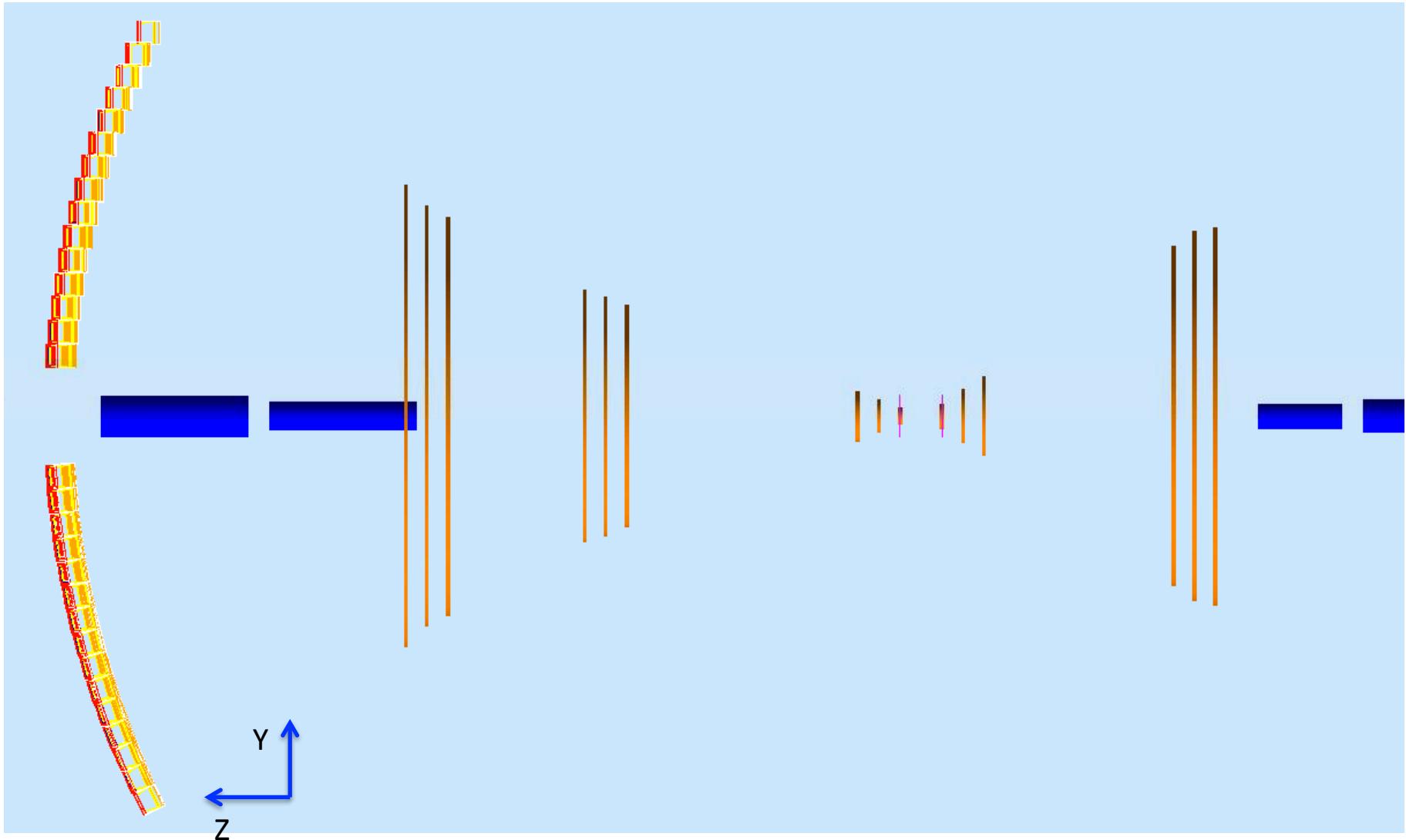


Need detailed design parameters for both **eta and phi projective**, no detector overlap, and minimum dead acceptance area.

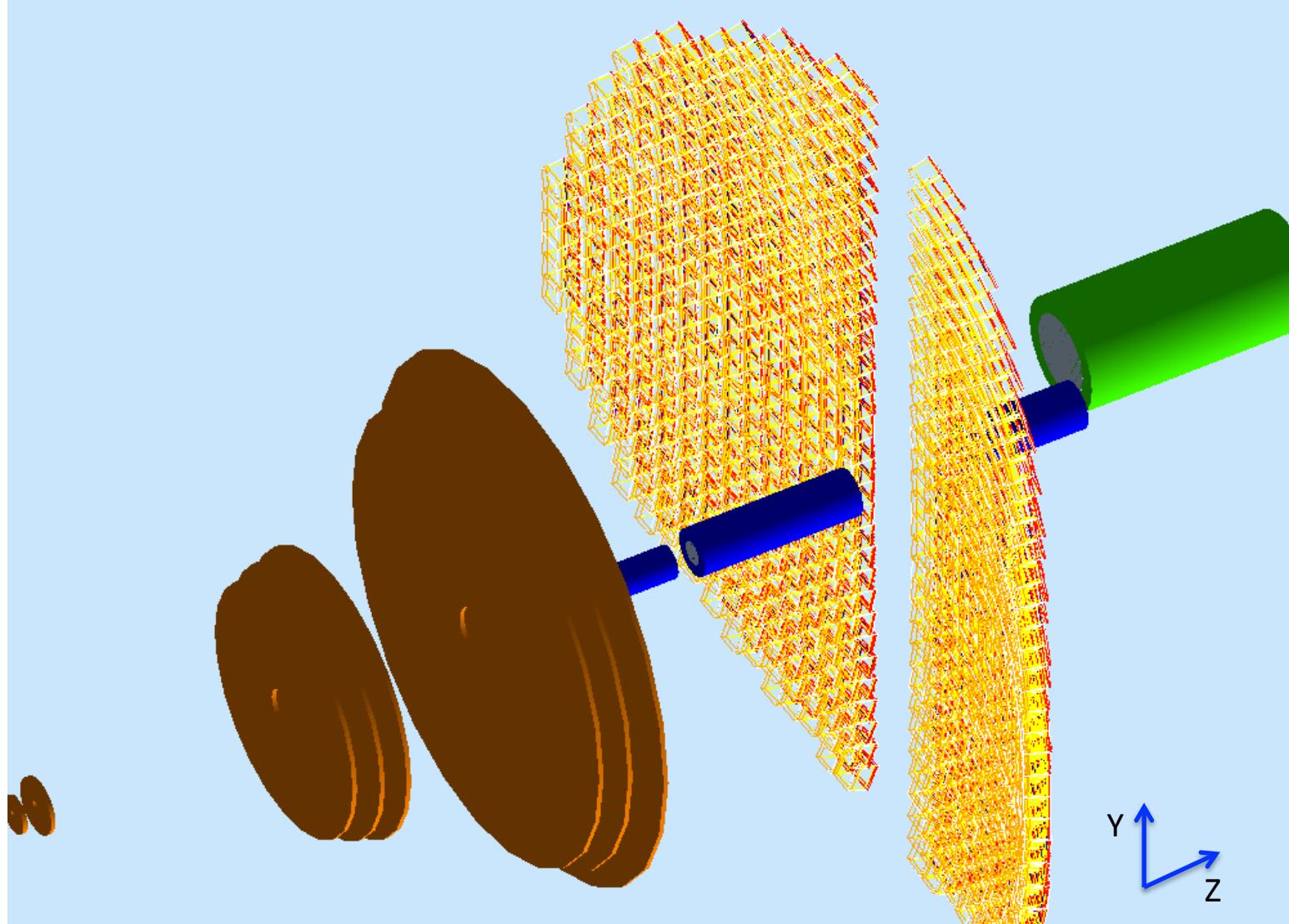
# Both Eta and Phi Projective (cnt)



# Modular RICH in MEIC



# Modular RICH in MEIC (cnt)



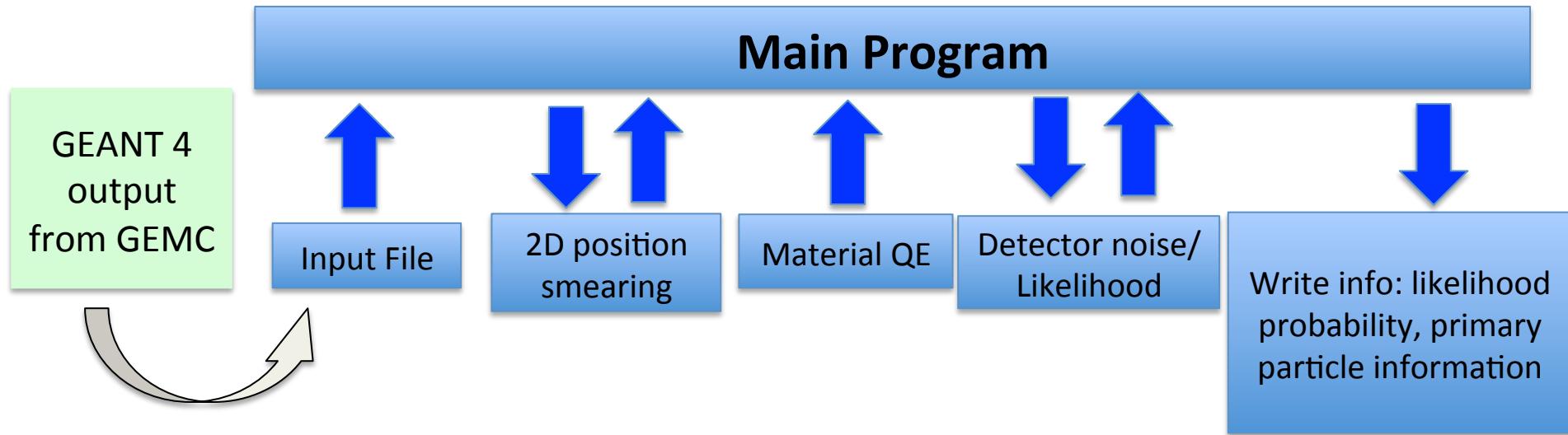
# Summary & Next

- Maximum likelihood analysis technique is optimized to study the PID performance for modular RHIC detector.
- Using optimized likelihood method:
  - We simulate  $\pi$ -, K-, proton with momentum from 3 to 15 GeV/c with different shoot location of the detector
  - Detector response database is stored with 3D histograms
  - PID efficiency decrease, and mis-PID increase a function of momentum.
  - At 10 GeV/c, PID efficiency are  $\pi$ -: 60%, K-: 55%, proton: 90%
  - PID performance with particle shoot the corner is worse than that with particle shoot the center of detector
- First try to stack modules together to make a real EIC RICH detector.
- More realistic simulation with pythia generator will be next.

# Backup Slides

# Analysis Framework

Framework:



Codes:

**include/**:

event.h    hit.h    material.h    likelihood.h    LLTreeDst.h

**src/**:

event.hxx    hit.hxx    material.hxx    likelihood.hxx

<https://github.com/EIC-eRD11>

# Detector Effects Implemented

- For 5 GeV  $\mu$ -, ~76 photons produced by aerogel, ~28 photons arrive at the photonsensor, ~11 photons left after quantum efficiency applied for GaAsP. Less optical photons for other particles.
- Perfect rings on photonsensor with photon reflected by fresnel lens.
- Photon position (2D gaussian) on photonsensor are smeared to mimic the “non-uniformity effect” of the aerogel and fresnel lens.
- Residual photons are used for PID analysis (rings finder, likelihood analysis).

